ECSE 416 – Intro to Telecom Networks – Fall 2020
Test 3
Nov. 23, 2020
Due Monday Nov. 30, 10am. Please scan your answers and submit the scanned pages as a single pdf file. Alternatively, you can prepare answers in electronic format and submit a single pdf.
5 questions, 60 marks

There are 5 questions. Marks allocated to each part are indicated in square brackets.

This exam is **open book**. You are permitted to consult any resources — textbook, web, notes. But do not discuss the questions and solutions with your classmates. Do not ask anyone else to help you solve the problems.

Question 1 [20 marks]

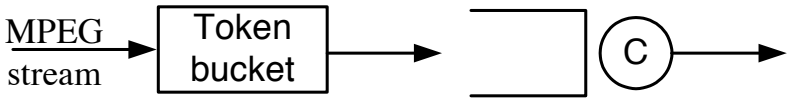

Figure 1: Shaper and queue for the MPEG video stream.

As in Fig. 1, A token bucket is used to shape an MPEG video stream. The token bucket has rate r = 0.15 Mbps (Mbps = Megabits per second), and burst size b = 15,000 bits. The output of the token bucket feeds into a buffered link with capacity C = 300 kbps.

a) Sketch the arrivals curve at the buffered switch if the MPEG traffic is being generated at such a rate that the traffic shaper is always busy. Make sure your sketch includes proper labels for the axes. Please read parts (a)-(c) to make sure your graph can show everything requested. **[3 marks]**

b) On the same graph, show the service curve of the buffered link. **[2 marks]**

c) For the buffered link, calculate the maximum backlog and the maximum delay. Show where these occur on your plot. **[5 marks]**

d) Let us assume that rather than going through a single buffered link, the traffic goes through three buffered links in succession. The rates of the first, second and third links are C_1 = 400 kbps, C_2 = 200 kbps, and C_3 = 300 kbps, respectively. Specify the service curve for the combination of three buffered links and hence determine the maximum backlog and the maximum delay in the network. **[4 marks]**

Now let us consider a VoIP system and the impact of fixed or adaptive playout delay.

e) Suppose first that the VoIP system uses a fixed playout delay of 400 ms. Three packets are received with timestamps 28.04, 28.08, and 28.12. The timestamp is expressed in seconds

relative to an arbitrary starting time. If the receiver's clock is synchronized with the sender's, when will the receiver play these packets out (relative to the same arbitrary start time). **[2 marks]**

f) The receiver changes to an adaptive playout mechanism. There is a silence period, and then a sequences of packets is received with timestamps 40.05, 40.07, 40.09. Prior to this burst, the average measured delay was 50 ms and the average deviation was 5ms. The measured delay for the first packet in this burst is 60ms. Suppose the VoIP receiver does one update of the adaptive playout parameters before playing out the sequence. It uses EWMAs with constants $\alpha = 0.1$ and $\beta = 0.1$. When calculating the playout time, the average delay deviation is multiplied by $K = 5$. At what times are the three packets played out? **[4 marks]**

Question 2 [10 marks]

Suppose there are 6 classes of traffic: A, B, C, D, E, F. In your design below, you have access to weighted fair queuing (WFQ) scheduling mechanisms and strict priority queuing (SPQ) mechanisms (in the latter one input always has priority over the other). The outgoing link has capacity 10 Mbps. Suppose you wish to satisfy the following requirements:

- Class A should always have priority over all other classes.
- Classes B and C should always have priority over classes D, E, and F.
- Class B should be allocated 3 times as much bandwidth as class C.
- Class D should be allocated 5 times as much bandwidth as class F.
- Class E should be allocated 4 times as much bandwidth as class F.

a) Assign each traffic class into one queue and draw a diagram to describe the queuing discipline. (Hint: you may need multi-level scheduling, where the output of one queue is the input of another.) **[6 marks]**

b) Complete the following table for this queuing system. Recall that the output rate of the entire link is 10 Mb/s. **[4 marks]**

Input Rates (Mb/s)						Output Rates (Mb/s)					
A	B	C	D	E	F	A	B	C	D	E	F
2	7	3	2	3	4						
1	1	1	6	1	2						
2	2	2	3	3	3						

Question 3 [10 marks]

Packets are arriving from two flows at a WFQ scheduler. The arrival times and packet sizes given as follows:

	Flow 1				Flow 2		
Packet Label	1a	1b	1c	1d	2a	2b	2c
Arrival Time	1	2	3	11	0	5	9
Packet Size	1	1	2	2	3	2	2

- Assume that the transmission rate is ($C = 1$), i.e., it takes one time unit to transmit a packet of size 1, two time units to transmit a packet of size 2, etc..
- Assume the two flows have weights such that the WFQ weight for flow 1 is $\phi_1 = 1/3$ and the weight for flow 2 is $\phi_2 = 2/3$.

a) Devise the transmission schedule of a fluid-flow WFQ scheduler (weighted GPS). Multiple packets can be sent in parallel, with bandwidth allocated according to the weights. The transmission schedule must specify, for each time interval, which packets are being transmitted and how much bandwidth is allocated to them. Make sure to provide the departure times of all packets. (Refer to individual packets using the labels given in the table). A figure can be used to depict this information, but please make sure it is very clear and everything important is labelled. **[4 marks]**

b) Determine the transmission schedule of a packet-level WFQ scheduler. Provide the departure times of all packets. (Refer to individual packets using the labels given in the table). **[4 marks]**

c) What is the maximum discrepancy between the departure times of any packet under the two scheduling approaches? What is the largest this value could be for any set of packet arrivals? **[2 marks]**

Question 4 [8 marks]

The iSLIP scheduling algorithm is a modification of PIM to avoid the randomness and improve fairness. It involves the following three steps:

- *Request*: Each input sends a request to every output for which it has a queued cell.
- *Grant*: If an output receives any requests, it chooses the one that appears next in a fixed, round-robin schedule starting from the highest priority element. The output notifies each input whether or not its request was granted. The pointer g_i to the highest priority element of the round-robin schedule is incremented (modulo N) to one location beyond the granted input.
- *Accept*: If an input receives a grant, it accepts the one that appears next in a fixed, round-robin schedule starting from the highest priority element. The pointer a_i to the highest priority element of the round-robin schedule is incremented (modulo N) to one location beyond the accepted output.

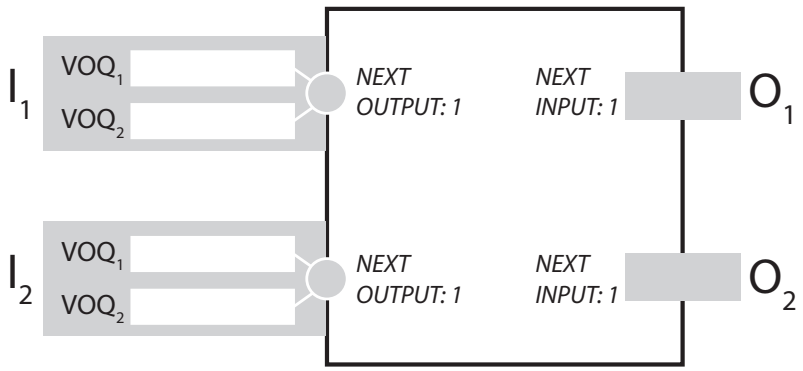

Figure 2: Switch with two inputs and two outputs using a VOQ mechanism and iSLIP scheduling.

a) Identify a set of packets in the virtual output queues (VOQs) of Figure 2 such that during the next time slot the iSLIP algorithm **takes 2 iterations to complete** and each output is given a packet to transmit. Assume that input 1 is the next input in both output 1's and output 2's round robin schedule. Explain how your solution works. **[4 marks]**

If

b) Identify a set of packets in the virtual output queues (VOQs) of Figure 2 such that during the next time slot the iSLIP algorithm **takes 1 iteration to complete** and each output is given a packet to transmit. Assume that input 1 is the next input in both output 1's and output 2's round robin schedule. Explain how your solution works. **[4 marks]**

Question 5 [12 marks]

- Your enterprise network is required to support 96 hosts and 3 servers (labelled D, E, F).
- You have been allocated the subnetwork 222.222.221.0/24. You have 3 openflow switches available to configure, labelled A, B, and C.
- You are required to group the hosts into three groups X, Y, and Z of equal size.
- Server D is a public-facing webserver that should be open to all internal users and available for secure connection requests from external users. Your network should be configured so that only appropriate, secure connections are permitted.
- Server E should be accessible to user groups X and Y, but not Z.
- Server F should be accessible to user groups X and Z, but not Y.
- Aside from the connections to the public server, no external parties should be able to communicate to internal hosts or servers. But all internal clients should be able to connect with external web servers.
- Only switch A should be connected to the public Internet. This should implement a NAT so that all emerging traffic has source address 222.222.221.17 (and all traffic to your network should be sent to this address).

Show how you could configure the switches using generalized forwarding flow tables to accomplish the configuration. Draw a diagram of your network providing clear labels of ports, IP addresses, server and client allocations. Provide the flow table for each switch.